



National Water-Quality Assessment Program

Organic Compounds and Trace Elements in Freshwater Streambed Sediment and Fish from the Puget Sound Basin

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As part of the National Water-Quality Assessment (NAWQA) Program, the USGS is investigating contaminants in streambed sediment and aquatic organisms and their relation to land use. One such study is being done in the Puget Sound Basin, which is located in northwestern Washington State and includes streams and rivers that drain to the Puget Sound, the Strait of Georgia, and the Strait of Juan de Fuca, but does not include marine waters. The basin encompasses 13,700 square miles; forest, urban, and agriculture are the principal land uses.

Summary of findings

Organochlorine compounds - Highest concentrations of organochlorine compounds in streambed sediment were at an urban site on Thornton Creek near Seattle, where total chlordane, DDT, DDD, and DDE were found to exceed Canadian sediment quality guidelines. Concentrations are compared to Canadian guidelines because there are no sediment quality guidelines in the State of Washington.

Highest concentrations of organochlorine compounds in sculpin (a bottom-feeding fish) were found at the Thornton Creek site. Polychlorinated biphenyls (PCBs) and total DDT (DDT+DDD+DDE) exceeded New York State criteria for protection of fish-eating wildlife at West Branch Kelsey Creek at Bellevue, another urban site. Concentrations are compared to New York State criteria because there are no criteria for protection of fish-eating wildlife in the State of Washington.

Effects - Elevated levels of organochlorine compounds such as DDT and PCBs are toxic to all animals and can bioconcentrate in tissue, cause tumors, and cause hormonal and behavioral problems. They can also suppress the immune and respiratory systems and cause abnormal development in aquatic species. The primary effect on aquatic communities is to reduce numbers of sensitive species, allowing species that are more resistant to contaminants to become dominant (Harte and others, 1991).

PAHs - Polycyclic aromatic hydrocarbon concentrations in streambed sediment exceeded Canadian guidelines in most urban streams and were highest at the West Branch Kelsey Creek at Bellevue.

Effects - Many PAHs, such as benzo(a)anthracene, benzo(a)pyrene, and chrysene, are carcinogenic, causing tumors in fish and other animals, and are acutely toxic to some organisms. Noncarcinogenic PAHs, such as fluoranthene, phenanthrene, and pyrene, are also toxic to some organisms. The effects on aquatic organisms of the PAHs found in sediment at Kelsey Creek are unknown, but concentrations of benzo(a)pyrene as high as those observed in this study can cause precancerous tumors in fish (Eisler, 1987).

Trace elements - Concentrations of arsenic, cadmium, lead, mercury, and zinc frequently exceeded forest and reference conditions in streambed sediment and sculpin in urban streams.

Effects - Elevated levels of arsenic, cadmium, lead, mercury, and zinc may not be of concern in a naturally metal-rich region such as Puget Sound because the aquatic system has adapted to this type of environment, but excessive amounts of these elements can affect the nervous, respiratory, circulatory, and reproductive systems of aquatic organisms, as well as affect their development and feeding habits (Rand and Petrocelli, 1985).



Urban stream

Data collection and analysis

Streambed sediment and whole sculpin tissue were analyzed to assess the occurrence and distribution of contaminants and to better understand the fate of contaminants in the environment (table 1). We collected samples in September 1995 from 18 sites, which were characterized on the basis of the predominant land use in the stream's basin—4 agricultural sites, 9 urban sites, 2 forest sites, and 3 reference sites, which are mostly forested and receive minimal impact from humans. At each site we collected the top 2-3 centimeters of streambed sediment in depositional areas; predatory bottom-feeding fish (sculpin) were collected from 17 of these sites. (See Crawford and Luoma, 1994, and Shelton and Capel, 1994, for a more complete description of the methods used.)

Table 1. Contaminants analyzed for in streambed sediment and whole sculpin tissue from the Puget Sound Basin.

Contaminant	Sediment ¹	Tissue
Organochlorine compounds	31 pesticides; total PCBs	26 pesticides; total PCBs
Other organic compounds	64	not analyzed ²
Trace elements	44	22

¹Finer than 2.0 millimeters for organic compounds, finer than 63.0 micrometers for trace elements.

²Tissue analysis too costly for this study

Fine-grained sediment and tissue accumulate trace elements and organic compounds associated with anthropogenic (human-related) activities. Sculpin are bottom-feeding fish that are not usually consumed by humans but are eaten by other fish and fish-eating wildlife. Organic compounds analyzed for were organochlorine pesticides, total PCBs, and other organic compounds (of the other organic compounds, only PAH values that exceeded Canadian guidelines are reported because they may have the most potential to harm aquatic and related organisms).

Evaluation of data

We compared our data to guidelines and criteria for organic compounds to show possible adverse effects to aquatic organisms and fish-eating wildlife, and to local forest and reference conditions for selected trace elements to show possible effects of land use (fig. 1).

Organic compounds - We compared levels of organochlorine compounds and PAHs detected in sediment to draft interim freshwater sediment quality guidelines developed by the Canadian Council of Ministers of the Environment (CCME). These guidelines were developed from toxicity and species abundance data for benthic organisms from studies throughout North America and represent total concentrations in sieved and unsieved sediment samples (CCME, 1995). The guidelines used are the threshold effects level (TEL), below which adverse effects to aquatic organisms are expected to occur **rarely**, and the probable effects level (PEL), above which adverse effects are predicted to occur **frequently**. Concentrations that exceed these guidelines may or may not have adverse effects on aquatic

organisms; the comparisons should be used to indicate **potential** sediment quality problems that may warrant further study.

We compared concentrations of organochlorine compounds in sculpin to New York State Department of Environmental Conservation (NYSDEC) criteria (Newell and others, 1987). These criteria were determined from laboratory experiments using fish-eating wildlife and are considered one of the best sets of criteria for evaluating the effects of contaminated fish tissue on wildlife.

Trace elements - We compared concentrations of selected trace elements in streambed sediment and sculpin tissue to median concentrations from the forest and reference sites. Land-use impacts may cause concentrations from the agricultural and urban sites to exceed these medians.



Agricultural stream

Constituents detected in

Sediment Tissue

Bertrand Creek near Lynden
arsenic
cadmium
chromium
nickel
zinc

Nooksack River at Brennan
chromium
nickel
zinc
arsenic
chromium
lead
mercury
nickel
zinc

Thornton Creek near Seattle
arsenic
cadmium
chromium
lead
mercury
nickel
zinc
DDT
arsenic
lead
mercury
PCBs

Duwamish River at golf course at Tukwila
arsenic
cadmium
lead
zinc
arsenic
mercury

Springbrook Creek at Tukwila
arsenic
cadmium
chromium
lead
mercury
nickel
zinc
no tissue sampled

Miller Creek near Des Moines
arsenic
cadmium
chromium
lead
mercury
nickel
zinc
arsenic
lead
mercury

North Fork Skokomish River at Staircase Rapids
arsenic
chromium
nickel
zinc
arsenic

Leach Creek near Steilacoom
arsenic
cadmium
chromium
lead
nickel
zinc
arsenic
zinc

Big Soos Creek above hatchery near Auburn
arsenic
cadmium
chromium
lead
nickel

Constituents detected in

Sediment Tissue

Fishtrap Creek at Flynn Road
arsenic
cadmium
chromium
lead
nickel
zinc
arsenic
mercury

Nooksack River at North Cedarville
nickel

North Creek below Penny Creek near Bothell
arsenic
cadmium
chromium
lead
mercury
nickel
zinc
arsenic
mercury

Juanita Creek at La Juanita
arsenic
cadmium
chromium
lead
nickel
zinc
arsenic
cadmium
lead
mercury

West Branch Kelsey Creek at Bellevue
arsenic
cadmium
chromium
lead
mercury
nickel
zinc
PAHs
arsenic
cadmium
lead
mercury
zinc
PCBs

Rock Creek at Cedar Falls near Landsburg
arsenic
cadmium
chromium
nickel
zinc

Rock Creek near Maple Valley
cadmium
lead
zinc
mercury

Green River above Twin Camp
mercury
arsenic
nickel
zinc

Newaukum Creek near Black Diamond
cadmium
lead
zinc

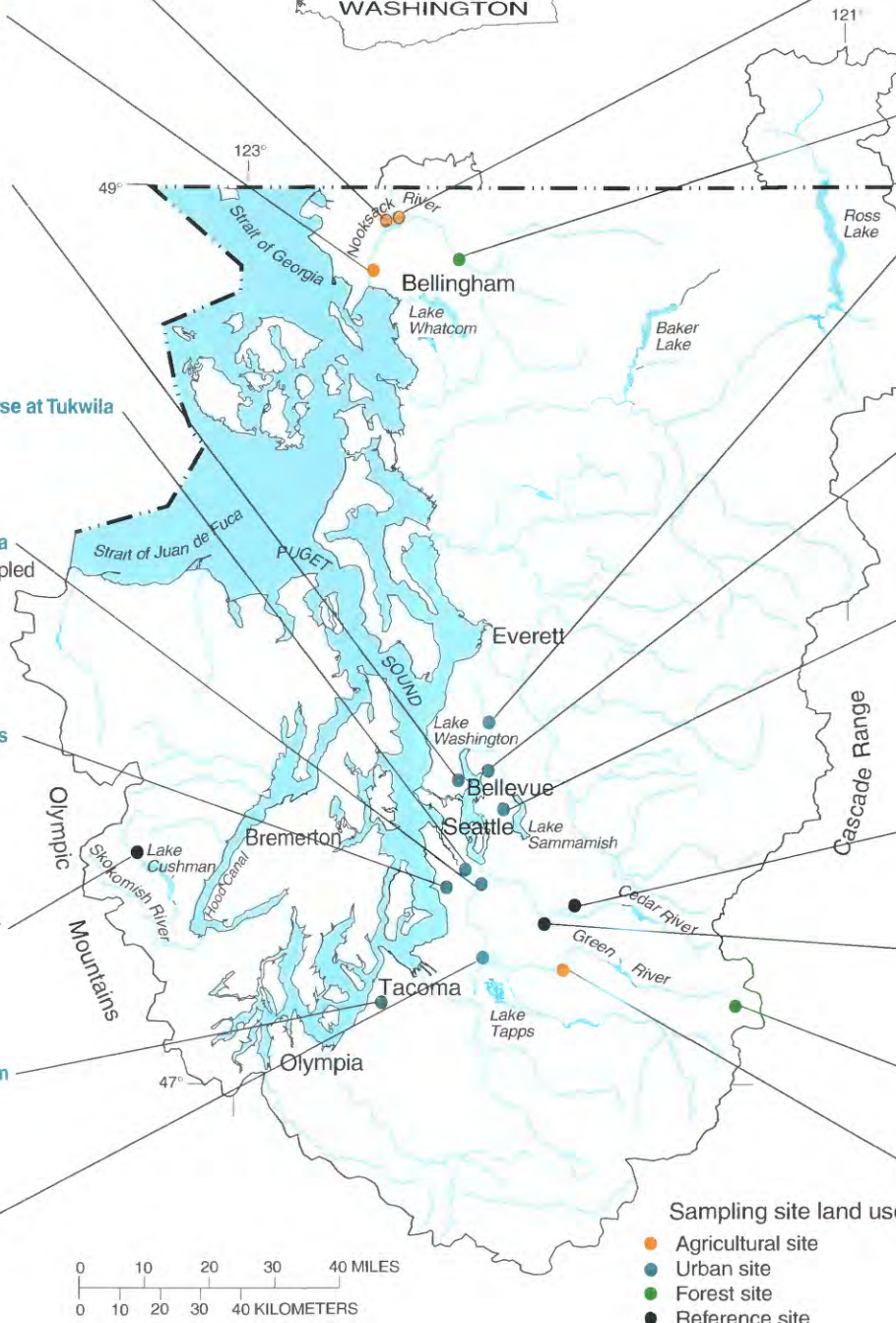


Figure 1. Organic compounds that exceed Canadian probable effects levels (PEL) and New York State Department of Environmental Conservation (NYSDEC) criteria, and trace elements that exceed median of forest and reference conditions at sampling sites in the Puget Sound Basin.

Organic compounds detected in streambed sediment

Organochlorine pesticides were detected at 3 of the 18 sites sampled for streambed sediment: an agricultural site on Fishtrap Creek in the northern part of the basin, an urban site on Thornton Creek near Seattle, and a reference site on Rock Creek near Maple Valley. The highest concentrations were found at the urban site on Thornton Creek (fig. 2).

PAHs were most frequently detected in streambed sediment samples from urban streams. The highest concentrations were found in the sample taken from West Branch Kelsey Creek at Bellevue (table 2).

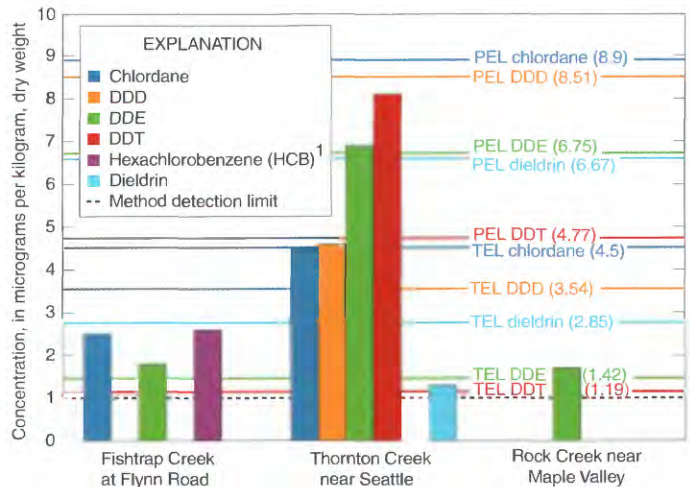


Figure 2. Concentrations of organochlorine pesticides in streambed sediment from selected sites in the Puget Sound Basin compared to Canadian criteria. (TEL, threshold effects level; PEL, probable effects level)

¹No published Canadian data for HCB

Table 2. Concentrations of polycyclic aromatic hydrocarbons (PAHs) in streambed sediment that exceed Canadian guidelines [values in micrograms per kilogram, dry weight; nd, not detected or below 50 micrograms per kilogram method detection limit; **bold**, above TEL; **red**, above PEL]

Site name	Benzo(a)anthracene ¹	Benzo(a)pyrene ²	Chrysene ¹	Fluoranthene ³	Phenanthrene ¹	Pyrene ³
Fishtrap Creek	54	53	50	91	nd	87
Duwamish River	52	nd	56	91	nd	79
Springbrook Creek	370	450	520	890	370	770
Juanita Creek	76	73	83	150	78	120
West Branch Kelsey Creek	680	1700	950	2800	850	2300
Leach Creek	57	62	65	100	51	94
Miller Creek	100	120	130	230	120	200
North Creek	nd	nd	nd	61	nd	56
Thornton Creek	220	310	270	470	200	410
Rock Creek near Maple Valley	270	nd	200	320	150	240
Rock Creek at Cedar Falls	50	54	63	nd	160	nd

¹Weakly carcinogenic (Eisler, 1987)

²Strongly carcinogenic

³Noncarcinogenic

Definitions of organic compounds found in the Puget Sound Basin

DDT (dichlorodiphenyltrichloroethane) is an organochlorine insecticide banned from use in the U.S. in 1972. Total DDT refers to the sum of DDT and its breakdown products DDE and DDD.

Chlordane is an organochlorine insecticide banned from use in the 1980's. Total chlordane refers to the sum of *cis*-chlordane, *trans*-chlordane, *cis*-nonachlor and *trans*-nonachlor.

HCB (hexachlorobenzene) is a fungicide used as a seed and soil treatment, restricted from use in the 1980's.

Dieldrin is an organochlorine insecticide with restricted use in the U.S. since the 1970's.

Heptachlor epoxide is a breakdown product of the organochlorine insecticide heptachlor. It was used in the U.S. until the 1970's.

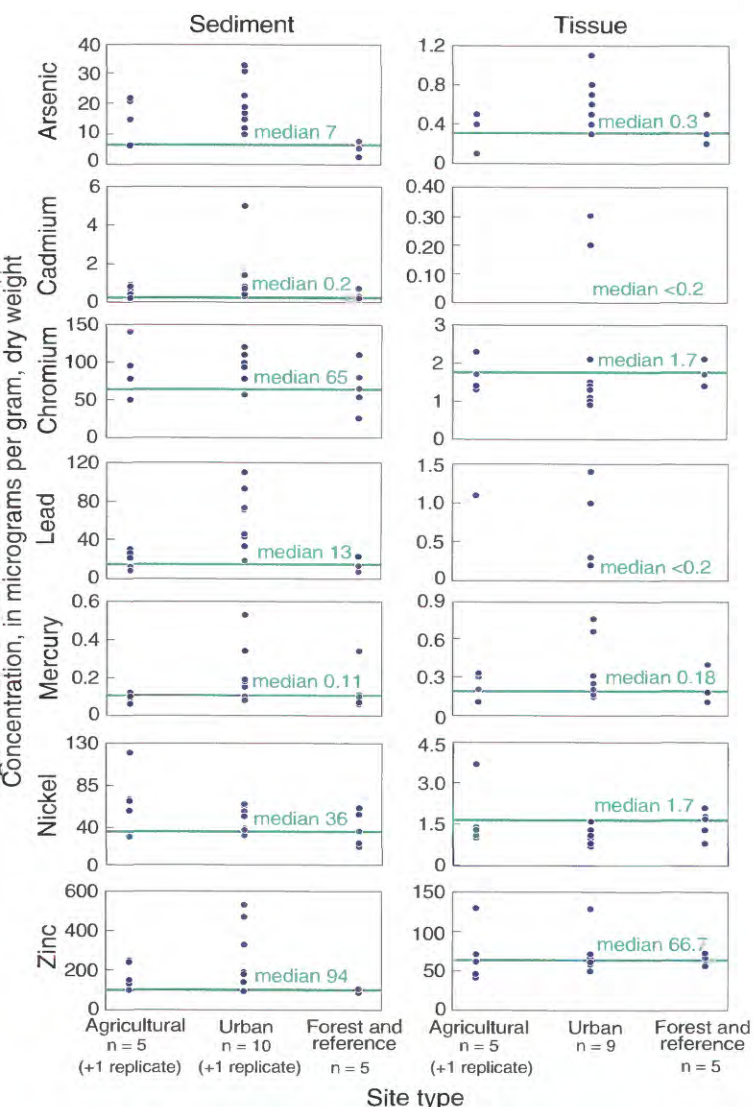
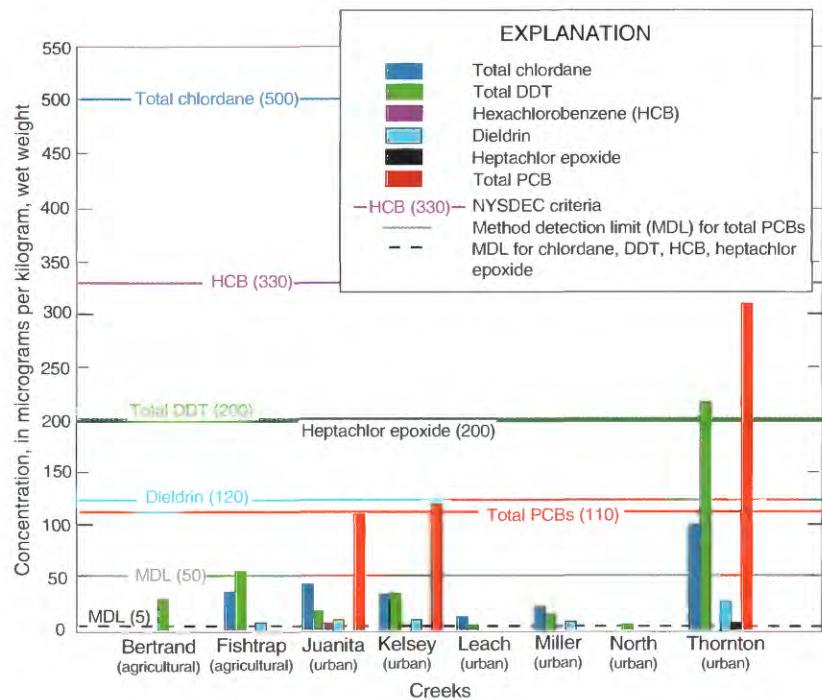
PCBs (polychlorinated biphenyls) are by-products of a variety of industrial products. Manufacture was stopped in the 1970's. There are over 209 breakdown products of PCBs, and total PCB refers to the sum of all forms detected.

PAHs (polycyclic aromatic hydrocarbons) are natural by-products of forest fires. Other sources include the steel and petroleum industry, the manufacture of coal tar and asphalt, power generation, burning trash, and vehicle emissions. Tons are emitted to the atmosphere and introduced to aquatic environments through oil spills and sewage discharge.

Organochlorine compounds detected in tissue

Total PCBs and/or at least 1 of 26 organochlorine pesticides were detected in tissue at 2 agricultural and 6 urban sites. The highest concentrations and greatest ranges of organochlorine compounds were detected at the Thornton Creek site (fig. 3).

Figure 3. Organochlorine compounds in whole sculpin tissue from selected creeks in the Puget Sound Basin compared to New York State Department of Environmental Conservation (NYSDEC) criteria.



Trace elements detected in streambed sediment and whole sculpin tissue

Concentrations of arsenic, cadmium, chromium, lead, mercury, nickel, and zinc were elevated in streambed sediment and sculpin from agricultural and urban sites compared to concentrations from the forest and reference sites. Arsenic and the heavy metals cadmium, lead, mercury, and zinc had the highest concentrations and the greatest range of concentrations at urban sites compared to those from the agricultural and the combined forest and reference sites, indicating possible enrichment of these elements in the urban areas (fig. 4). The concentrations detected do not necessarily have negative impacts on the environment, but do suggest that land use may have led to increased levels of these elements.

Figure 4. Concentrations of selected trace elements detected in streambed sediment and whole sculpin tissue collected in the Puget Sound Basin compared to the median of forest and reference site data. (n, number of samples; +1 replicate, one replicate sample data included; <, less than)

For data used in the development of this fact sheet or for information on the Puget Sound Basin NAWQA, contact:

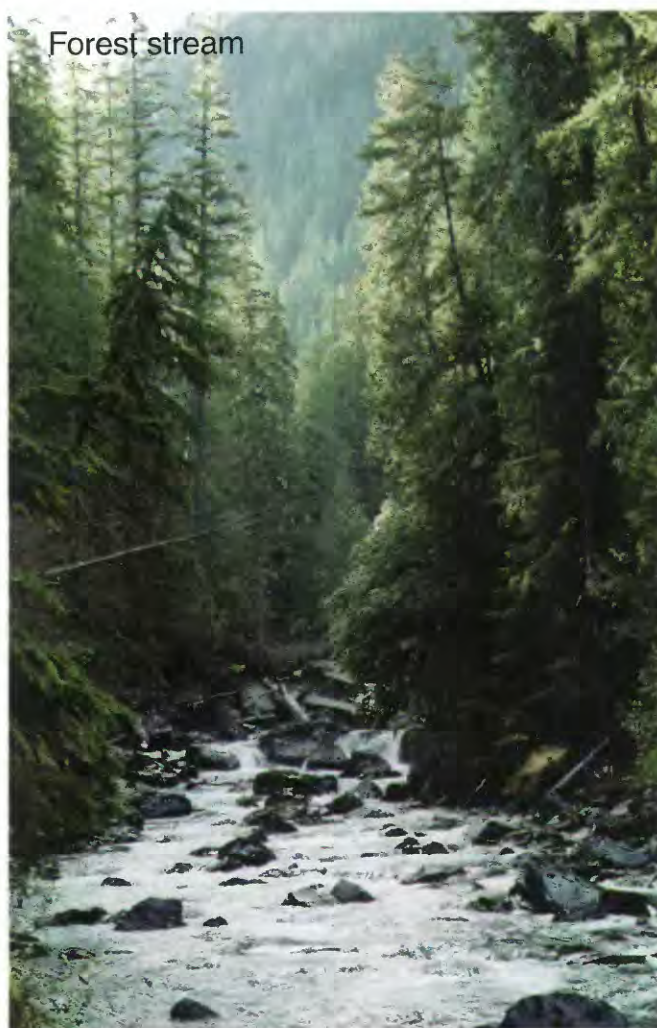
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Riffle sculpin, *Cottus gulosus*

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